

FORM PTO-1390 (Modified)  
(REV 10-95)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371

1788

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR

10/018932

INTERNATIONAL APPLICATION NO.  
PCT/DE 00/01629INTERNATIONAL FILING DATE  
MAY 20, 2000PRIORITY DATE CLAIMED  
JUNE 19, 1999

TITLE OF INVENTION

PIEZOELECTRIC ACTUATOR

APPLICANT(S) FOR DO/EO/US

Friedrich BOECKING

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
  - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☒ has been transmitted by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ A copy of the International Search Report (PCT/ISA/210).
8. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
  - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☐ have been transmitted by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☐ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

## Items 13 to 18 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.  
A **SECOND** or **SUBSEQUENT** preliminary amendment.
16. ☐ A substitute specification.
17. ☐ A change of power of attorney and/or address letter.
18. ☒ Certificate of Mailing by Express Mail
19. ☐ Other items or information:

ET 755324243 US

U.S. APPLICATION NO. (IF KNOWN) SEE 37 CFR 1.53(a) <b>10/018932</b>	INTERNATIONAL APPLICATION NO. <b>PCT/DE 00/01629</b>	ATTORNEY'S DOCKET NUMBER <b>1788</b>
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20. The following fees are submitted:

**BASIC NATIONAL FEE ( 37 CFR 1.492 (a) (1) - (5) ) :**

- ☐ Search Report has been prepared by the EPO or JPO ..... **\$930.00**
- ☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) ..... **\$720.00**
- ☐ No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) ..... **\$790.00**
- ☒ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... **\$1,070.00**
- ☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) ..... **\$98.00**

**ENTER APPROPRIATE BASIC FEE AMOUNT =****\$890.00**

Surcharge of **\$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).

**\$0.00**

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE
Total claims	7 - 20 =	0	x \$18.00
Independent claims	1 - 3 =	0	x \$80.00

**\$0.00****\$0.00**Multiple Dependent Claims (check if applicable). ☐**\$0.00****TOTAL OF ABOVE CALCULATIONS =****\$890.00**

Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) (check if applicable). ☐

**\$0.00****SUBTOTAL =****\$890.00**

Processing fee of **\$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)).

**\$0.00****TOTAL NATIONAL FEE =****\$890.00**

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable). ☒

**\$40.00****TOTAL FEES ENCLOSED =****\$930.00**

Amount to be: refunded	\$
charged	\$

☐ A check in the amount of \_\_\_\_\_ to cover the above fees is enclosed.

☒ Please charge my Deposit Account No. **19-4675** in the amount of **\$930.00** to cover the above fees.  
A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **19-4675** A duplicate copy of this sheet is enclosed.

**NOTE:** Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

**STRIKER, STRIKER & STENBY**  
103 EAST NECK ROAD  
HUNTINGTON, NEW YORK 11743

SIGNATURE

**MICHAEL J. STRIKER**

NAME

**27233**

REGISTRATION NUMBER

**DECEMBER 19, 2001**

DATE

**UNITED STATES PATENT AND TRADEMARK OFFICE**

Our Docket No.: 1788

*In re:*

*Applicant:* BOECKING

*Serial No.:*

*Filed:*

*For:*

***SIMULTANEOUS AMENDMENT***

December 19, 2001

Hon. Commissioner of  
Patents and Trademarks  
Washington, D.C. 20231

Sir:

Simultaneously with filing of the above identified application,  
please amend the same as follows:

In the specification:

Please amend the specification as attached.

In the claims:

Cancel all claims without prejudice.

Add the following claims as attached.

REMARKS

This Amendment is submitted simultaneously with filing of the above identified application.

With the present Amendment applicant has amended the specification to bring it in compliance with the requirements of the U.S. Patent Practice.

The original claims have been canceled and replaced with a new set of claims which has been drafted also in accordance with the requirements of the U.S. Patent Practice.


Consideration and allowance of present application is most respectfully requested.

Should the Examiner require or consider it advisable that the specification, claims and/or drawings be further amended or corrected in formal respects in order to place this case in condition for final allowance, then it is respectfully requested that such amendments or corrections be carried out by Examiner's Amendment, and the case be passed to issue.

10016932-122801

Any costs involved should be charged to the deposit account of the undersigned (No. 19-4675). Alternatively, should the Examiner feel that a personal discussion might be helpful in advancing this case to allowance, he is invited to telephone the undersigned (at 631-549-4700).

Respectfully submitted,



Michael J. Striker  
Attorney for Applicants  
Reg. No. 27233

In the specification:

**Page 1, line 3, change the heading “Prior Art” to --  
Background of the Invention --.**

**Amend the first paragraph on page 1 as follows:**

The invention concerns a piezoelectric actuator, e.g., to actuate a mechanical component such as a valve or the like[, according to the features-based on the general class-of the primary claim].

**On page 1, line 21, change the heading “Advantages of the Invention” to -- Summary of the Invention --.**

**After this heading please insert the following paragraph:**

-- In keeping with these objects and with others which will become apparent hereinafter, one feature of present invention resides, briefly stated in a piezoelectric actuator, comprising a multilayer structure of piezoelectric plies; internal electrodes and external electrodes, said internal

electrodes being arranged between said piezoelectric plies and having a lateral contacting in alternate direction of said internal electrodes with said external electrodes having two different polarities, two consecutive internal electrodes having a same polarity always comprise one internal electrode always having the other polarity between them and having a common contact point with their assigned external electrode, one of the two internal electrodes having the same polarity passing all the way through the piezoelectric actuator from a side of its contacting with said external electrode to an opposite side, the other internal electrode having the same polarity always terminating with clearance on a side of the piezoelectric actuator opposite to its contacting, the internal electrode passing all the way through the piezoelectric actuator terminating in a region of the piezoelectric actuator that is bridged over to prevent a short circuit of said external throat arranged there. --

**On page 3, in line 24, change the heading "Diagram" to --  
Brief Description of the Drawings --.**

**On page 4, line 8, change "Description of the Exemplary  
Embodiments" to -- Description of the Preferred Embodiments --.**



**Amended paragraph 1, on page 1:**

The invention concerns a piezoelectric actuator, e.g., to actuate a mechanical component such as a valve or the like.

**On page 1, after the heading “Summary of the Invention”, please insert the new paragraph:**

-- In keeping with these objects and with others which will become apparent hereinafter, one feature of present invention resides, briefly stated in a piezoelectric actuator, comprising a multilayer structure of piezoelectric plies; internal electrodes and external electrodes, said internal electrodes being arranged between said piezoelectric plies and having a lateral contacting in alternate direction of said internal electrodes with said external electrodes having two different polarities, two consecutive internal electrodes having a same polarity always comprise one internal electrode always having the other polarity between them and having a common contact point with their assigned external electrode, one of the two internal electrodes having the same polarity passing all the way through the piezoelectric actuator from a side of its contacting with said external

electrode to an opposite side, the other internal electrode having the same polarity always terminating with clearance on a side of the piezoelectric actuator opposite to its contacting, the internal electrode passing all the way through the piezoelectric actuator terminating in a region of the piezoelectric actuator that is bridged over to prevent a short circuit of said external throat arranged there. --

New claims:

8. A piezoelectric actuator, comprising a multilayer structure of piezoelectric plies; internal electrodes and external electrodes, said internal electrodes being arranged between said piezoelectric plies and having a lateral contacting in alternate direction of said internal electrodes with said external electrodes having two different polarities, two consecutive internal electrodes having a same polarity always comprising one internal electrode always having the other polarity between them and having a common contact point with their assigned external electrode, one of the two internal electrodes having the same polarity passing all the way through the piezoelectric actuator from a side of its contacting with said external electrode to an opposite side, the other internal electrode having the same polarity always terminating with clearance on a side of the piezoelectric actuator opposite to its contacting, the internal electrode passing all the way through the piezoelectric actuator terminating in a region of the piezoelectric actuator that is bridged over to prevent a short circuit of said external electrode arranged there.

9. A piezoelectric actuator as defined in claim 8; and further comprising an insulation layer applied in a region in which said internal electrode extended from a non-contacted side of the end terminates.

10. A piezoelectric actuator as defined in claim 8, wherein said external electrodes are composed of an electrically conductive material selected from the group consisting of a metal strip, a screen, and a net.

11. A piezoelectric actuator as defined in claim 8, wherein said external electrodes are composed of wave electrodes that bridge over the other internal electrode extended to an end of the piezoelectric ply and not to be contacted, at a specific distance in a shape of a wave.

12. A piezoelectric actuator as defined in claim 8, wherein said multilayer structure of piezoelectric plies is provided with an electrically insulating ceramic plate at each end of said piezoelectric plies.

13. A piezoelectric actuator as defined in claim 8, wherein said piezoelectric actuator is formed so that it is usable to actuate a mechanical component.

14. A piezoelectric actuator as defined in claim 8, wherein said piezoelectric actuator is formed as a valve.

## PIEZOELECTRIC ACTUATOR

## Prior Art

The invention concerns a piezoelectric actuator, e.g., to actuate a mechanical component such as a valve or the like, according to the features—based on the general class—of the primary claim.

It is generally known that, by utilizing the “piezoelectric effect”, a piezoelectric element can be constructed out of a material having a suitable crystal structure. When an external electrical voltage is applied, a mechanical reaction of the piezoelectric element takes place that, depending on the crystal structure and the application regions of the electrical voltage, represents a push or pull in a specifiable direction. The construction of this piezoelectric actuator can take place here in a plurality of layers (multilayer actuators), and each of the electrodes, via which the electrical voltage is applied, is arranged between the layers. When the piezoelectric actuator is operated, care must be taken to ensure that no disturbing crack formations develop in the ply structure by means of mechanical stresses.

## Advantages of the Invention

The piezoelectric actuator described initially, which can be used to actuate a mechanical component, for example, is advantageously constructed with a multilayer structure of piezoelectric plies and electrodes arranged between them. With a lateral contacting of the electrodes in alternate directions, a neutral phase forms in the region between two piezoelectric plies in each case. Since the electrodes contacted on one side in each case are integrated in the ply structure in the manner of a comb, the consecutive electrodes in the direction of the ply build-up must be contacted on opposite sides, always in alternating fashion.

As a rule, the electrodes contacted on one side can thereby not always be extended completely to the opposite side, because voltage spark-overs could otherwise lead to the destruction of the piezoelectric actuator. When the piezoelectric actuator is operated, i.e., when a voltage is applied between the opposing electrodes in the ply structure, different mechanical forces occur in the region of the electrodes as well as in the non-contacted neutral phases, which can lead to mechanical stresses and crack formations in the piezoelectric actuator.

In an advantageous exemplary embodiment according to the invention, one electrode layer of the internal electrode that is contacted on one side is always extended completely to the end of the other side at specified intervals, and the external electrode lying on the other side in each case thereby bridges over this layer to prevent a short circuit. The contacting in alternate directions is constructed in such a fashion that two internal electrodes—that enclose an internal electrode having the opposite polarity and contacted on the opposite side—are contacted jointly on one side in each case. In alternating fashion, one of these jointly contacted internal electrodes—with formation of a neutral phase—is now not extended to the end of the piezoelectric plies in each case, and the other is extended to the end of the piezoelectric ply in each case.

A contacting with external electrodes is possible in which an insulation layer is applied in simple fashion in the region in which the other internal electrode extended on the non-contacted side to the end lies. The external electrodes can thereby be composed of an electrically conductive screen or net. The form of the external electrode can also be a simple metal strip here, and this can be composed of a conductive material with similar coefficients of thermal expansion as the ceramic material of the piezoelectric plies, e.g., invar.

In another preferred embodiment, however, the external electrodes are advantageously wave electrodes that bridge over the other internal electrode—

extended to the end of the piezoelectric ply and not to be contacted—at a specified distance in the shape of a wave.

With the exemplary embodiments named previously, it is therefore possible to extend every other internal electrode to the outside via partial external contacting. With this measure and a partially offset external electrode, e.g., a wave electrode which is connected only in the region of the external contacting and which has a distance of approximately 50  $\mu\text{m}$ , for example, from the internal electrode not to be contacted, a short circuit can be avoided here and the expansion in the external region—by the reduction of the neutral phase—can be increased markedly overall, so that the risk of crack formation is reduced.

It is furthermore advantageous when the multilayer structure of the piezoelectric plies is provided with an electrically insulating ceramic plate on each end of the folded layers.

These and further features of preferred further developments of the invention also arise from the description and the diagrams in addition to the claims, and each of the individual features can be realized on its own or in plurality in the form of sub-combinations in the exemplary embodiment of the invention and in other fields, and can represent advantageous and patentable embodiments in themselves, for which protection is claimed here.

#### Diagram

Exemplary embodiments of the piezoelectric actuator according to the invention are explained using the diagram.

Figure 1 shows a sectional view through a piezoelectric actuator with a multilayer structure of plies composed of piezoelectric ceramic and having contacted



internal electrodes in alternate directions and external electrodes designed in the shape of a wave; Figure 2 shows a side view along the line A-A of Figure 1, and Figure 3 shows a partial sectional view of an exemplary embodiment having insulated regions in the region of each non-contacted internal electrode extended toward the outside.

#### Description of the Exemplary Embodiments

A piezoelectric actuator 1 is shown in Figure 1 that is constructed in a fashion known per se out of piezoelectric films 2 of a quartz material having a suitable crystal structure, so that, by utilizing the "piezoelectric effect" when applying an external electrical voltage to internal electrodes 3 and 4 as well as 5 and 6, etc. by way of external electrodes 7 and 8 contacted externally, a mechanical reaction of the piezoelectric actuator 1 takes place.

It is furthermore obvious in Figure 1 that the external electrodes are designed as wave electrodes 7 and 8 that are always contacted at contact surfaces 9 and 10 with two internal electrodes having the same polarity. Every other internal electrode 3, 5 or 4, 6 having the same polarity in each case is continuous to the other end of the piezoelectric actuator 1 and is hereby insulated from this by means of a wave 11 of the respective external electrode 7 and 8 not to be contacted.

One electrically insulating head plate 12 and one foot plate 13 each are also applied to the external piezoelectric plies of the films 2, by means of which the entire piezoelectric actuator 1 can be insulated toward the outside.

To illustrate the exemplary embodiment according to Figure 1, a side view along A-A from Figure 1 is shown in Figure 2, in which a top view of the external

1 electrode 8 can be seen. The same components are labelled with the identical  
2 reference numerals here.

3

4 A second exemplary embodiment of a piezoelectric actuator 1 having another  
5 external contacting 16 is shown in Figure 3. A simple metal foil 14 is available  
6 here as the external electrode, which touches an insulation layer 15 applied in-  
7 between in the region of the internal electrodes 5, etc. not to be contacted. The  
8 same effect can therefore be achieved as in the exemplary embodiment  
9 according to Figures 1 and 2.

10

11

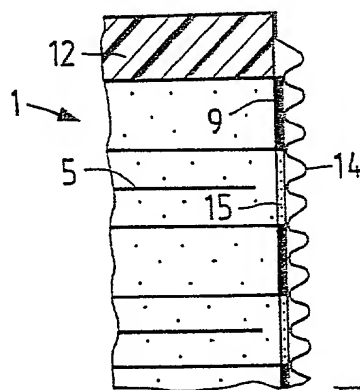
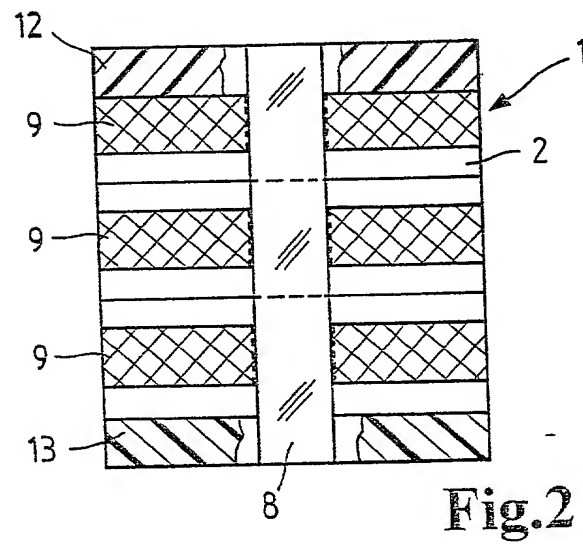
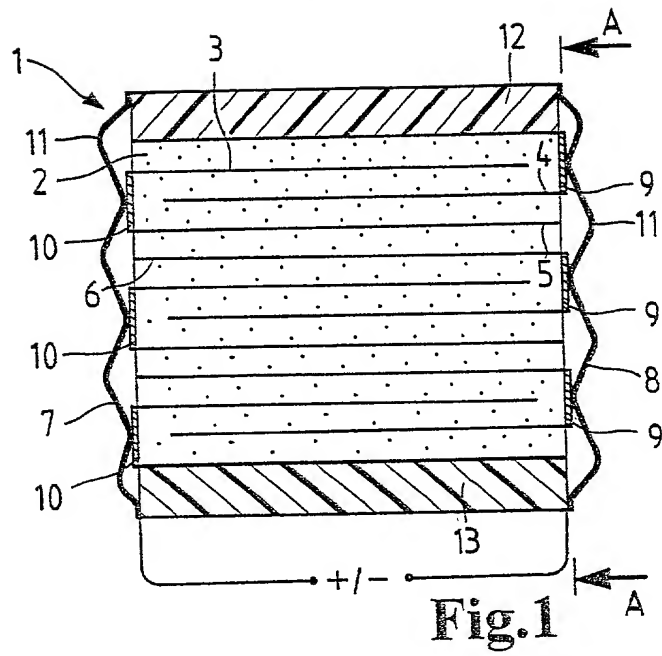
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## Claims

1. Piezoelectric actuator with
  - a multilayer structure of piezoelectric plies (2) and internal electrodes (3, 4, 5, 6) arranged between them,
  - a lateral contacting of the internal electrodes (3, 4, 5, 6) with external electrodes (7, 8; 14) in alternate directions, wherein, in the region between two piezoelectric plies (2), comprises an internal electrode (3, 5 or 4, 6) contacted on the opposite side in each case, a neutral phase without electrode layer is available on the other side in each case, wherein
    - at specified intervals, one electrode layer of the internal electrode (5, 6) that is contacted (9, 10) on one side always extends completely to the end of the other side, and the external electrode (7, 8) lying on the other side in each case thereby bridges over this layer to prevent a short circuit.
2. Piezoelectric actuator according to Claim 1, characterized in that
  - the contacting in alternate directions is designed in such a fashion that two internal electrodes (3, 5), which enclose an internal electrode (4) having opposite polarity, are contacted (10) jointly on one side in each case, wherein, in alternating fashion, one internal electrode (3), with formation of the neutral phase, is not extended to the end of the piezoelectric plies (2) in each case, and the other (5) extends to the end of the piezoelectric ply (2) in each case.
3. Piezoelectric actuator according to Claim 1 or 2, characterized in that
  - an insulation layer (15) is applied in the region in which the other internal electrode (5) extended on the non-contacted side to the end lies.
4. Piezoelectric actuator according to Claim 3, characterized in that

- 1 - the external electrodes (14) are composed of an electrically conductive  
2 metal strip, a screen, or net.  
3
- 4 5. Piezoelectric actuator according to Claim 1, 2 or 3, characterized in that  
5 - the external electrodes are composed of wave electrodes (7, 8) that bridge  
6 over the other internal electrode (5, 6)—which is extended to the end of  
7 the piezoelectric ply (2) and is not to be contacted—at a specified distance  
8 in the shape of a wave.  
9
- 10 6. Piezoelectric actuator according to one of the preceding claims,  
11 characterized in that  
12 - the multilayer structure of piezoelectric plies (2) is provided with an  
13 electrically insulating ceramic plate (12, 13) on each end of the folded  
14 layers.  
15
- 16 7. Piezoelectric actuator according to one of the preceding claims,  
17 characterized in that  
18 - the piezoelectric actuator (1) for actuating a mechanical component can  
19 be used like a valve or the like.

1 / 1



**DECLARATION AND POWER OF ATTORNEY FOR NATIONAL STAGE OF PCT PATENT APPLICATION**

As a below-named inventor, I hereby declare that:

Friedrich BOECKING

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **PIEZOELECTRIC ACTUATOR** the specification of which was filed as PCT International Application number PCT/DE 00/01629 on May 20, 2000.

I hereby state that I believe the named inventor or inventors in this Declaration to be the original and first inventor or inventors of the subject matter which is claimed and for which a patent is sought.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365 (b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior foreign application(s):

Priority claimed:

<u>199 28 187.4-35</u>	<u>GERMANY</u>	<u>JUNE 19, 1999</u>	<u>X</u>	
(Number)	(Country)	(Date filed)	Yes	No
<u>                    </u>	<u>                    </u>	<u>                    </u>	<u>Yes</u>	<u>No</u>
(Number)	(Country)	(Date filed)	Yes	No

As a named inventor, I hereby appoint the following attorney to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Michael J. Striker, Reg. No. 27233

Direct all telephone calls to Striker, Striker & Stenby at telephone no.: (631) 549 4700 and address and all correspondence to:

STRIKER, STRIKER & STENBY  
103 East Neck Road  
Huntington, New York 11743  
U.S.A.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statement may jeopardize the validity of the application or any patent issued thereon.

Signature: <i>Friedrich Boecking</i>	Date: <i>14.8.01</i>	Residence and Full Postal Address: Mainzer Strasse 27 70499 Stuttgart Germany
Full Name of First or Sole Inventor: Friedrich BOECKING	Citizenship: GERMAN <i>DEX</i>	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Second Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Third Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Fourth Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Fifth Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Sixth Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Seventh Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Eighth Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Ninth Inventor:	Citizenship:	

FRIEDRICH BOECKING